How Much Time Is Safety Worth? A Comparison of Trigger Configurations on Pneumatic Nail Guns in Residential Framing

Hester J. Lipscomb, PhD[a]
James Nolan[b]
Dennis Patterson[b]
Dimitrios Makrozahopoulos, BS, MIE[c]
Kristen L. Kucera, PhD, ATC[a]
John M. Dement, PhD, CIH[a]

SYNOPSIS

Objective. Nail gun injuries are among the most common in wood frame construction. Despite evidence that the majority of injuries from unintentional firings could be prevented with a sequential trigger mechanism on the tools, the safer trigger has not been embraced in the fast-paced residential construction industry. An experiment was conducted in an attempt to realistically evaluate the magnitude of productivity concerns.

Methods. Ten journeymen carpenters built a yard shed on two occasions, using nail guns with two different trigger configurations, alternately, under controlled conditions. Mean differences in time required, nails used, and proper placement were evaluated considering the trigger used and whether the building was the carpenter's first or second project.

Results. The sequential trigger tool required a mean of 10 additional minutes of active nailing time, which represented 10% of mean nailing time (97 minutes) but only 0.77% of the total mean work time (1,298 minutes) to construct each shed. No significant differences were observed in nail count or placement. The majority of the time variability was related to who was using the tool, rather than the type of tool in the person's hand.

Conclusions. Productivity concerns should focus more on improving the skill of the carpenter rather than on the trigger mechanism. Failure to place tools with the safer trigger configuration, which requires the nose piece to be depressed before the trigger is pulled, in the hands of workers does not make sense given the frequency and potential repercussions of injuries associated with the use of these tools in wood framing.

[a]Division of Occupational and Environmental Medicine, Department of Community and Family Medicine, Duke University Medical Center, Durham, NC

[b]Carpenters District Council of Greater St. Louis and Vicinity, St. Louis, MO

[c]Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, NC

Address correspondence to: Hester J. Lipscomb, PhD, Division of Occupational and Environmental Medicine, Department of Community and Family Medicine, Duke University Medical Center, Box 3834, Durham, NC 27710; tel. 919-286-3232; fax 919-286-1620; e-mail <hester.lipscomb@duke.edu>.

Nail guns, designed to increase productivity by rapidly sinking nails into dense wood, are used extensively in residential framing. The primary energy source for the nail guns used in wood framing is pneumatic air pressure supplied by a compressor. Injuries from these tools are now one of the more common in wood frame construction.[1–3] Most of the injuries involve puncture wounds to the hands and fingers.[2–6] There is also documentation that the injuries can be costly and serious,[7–10] involving fractures, wound infections, internal injuries,[7,11–15] and even fatalities.[16–18]

Unintentional discharges of nails are prevented through the combination of a manual trigger and a contact element in the nose of the gun.[19] The more common contact trip trigger configuration allows nails to be discharged from the tool anytime the nose and the trigger mechanism are both depressed. This configuration allows the user to "bump nail" by holding a finger on the trigger and bouncing the nose piece of the tool on the work surface. While the recoil that follows nail placement may facilitate this rapid-fire nailing, it also can result in unintentional placement of the nose piece with subsequent ricocheting or projectile nails if the user has the trigger depressed. Trigger blocks or other user modifications that keep the trigger depressed allow the tool to discharge nails anytime the nose piece comes in contact with anything, including appropriate or inappropriate work surfaces, the user, or a coworker.

Data indicate that the majority of injuries from unintentional firings could be prevented if the tools had an alternative sequential trigger mechanism, which requires the nose to be depressed before the trigger is pulled for the tool to discharge a nail.[4,5,20] Despite this growing documentation of injury associated with unintentional firing of the contact trip tool, the sequential trigger mechanism has not been embraced in the residential construction industry. Residential building is a fast-paced work environment and concerns about decreased speed associated with the sequential trigger have been raised by both contractors and carpenters.

In light of these concerns and a tight residential market, an experiment was conducted in an attempt to realistically evaluate productivity variability. We report on time differences, as well as nail placement and count, observed in a residential framing project performed under controlled conditions using pneumatic nail guns with these two different trigger configurations.

MATERIALS AND METHODS

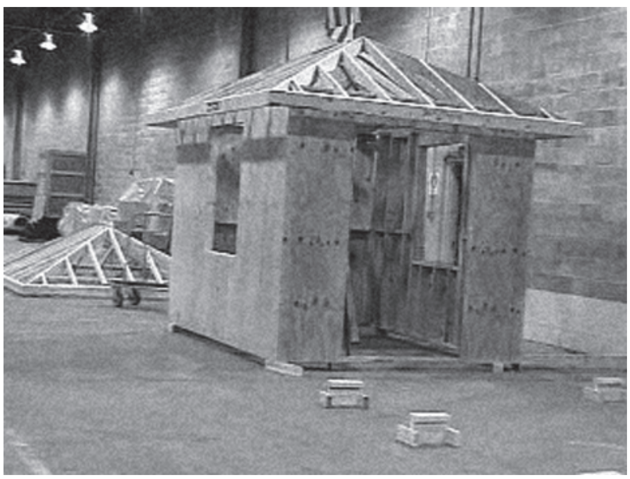
Participants

Ten journeymen carpenters were recruited to build a yard shed on two occasions at least two weeks apart. The sheds were built at the Carpenters Joint Apprenticeship Program (CJAP) in St. Louis, Missouri. Each carpenter built one shed with each of the two trigger configurations. Alternating, half used the sequential trigger first while the other half used the contact trip first. In each case, the journeymen came to the apprenticeship school in the afternoon after work. Participants also completed a short administered questionnaire inquiring about their age, length of union membership, time in the trade, use of nail guns, and current type of work.

To be eligible to participate, each carpenter had to be an active union member with health insurance benefits and have used nail guns with both contact and sequential trigger configurations. Participation was after informed consent, and each participant received $100 for building two sheds. All procedures were approved by the Institutional Review Board at Duke University Medical Center and the Center to Protect Workers Rights, the research arm of the Building Trades, American Federation of Labor–Congress of Industrial Organizations. Participants were required to wear hard hats, safety glasses, and work boots, and a spotter was assigned to stop any worker using the tool in a manner not intended by the manufacturer, although this was never necessary. Trainers from CJAP and the Southern Illinois Carpenters Training Center in Belleville, Illinois, assisted.

The building project

Before recruitment of participants, plans were drafted for the shed and a prototype building was completed by a journeyman carpenter. The 8-by-10-foot shed had a hip roof with a 1-foot overhang, as well as a framed door and window opening (see photo). The



Example of shed constructed in experimental building protocol.

walls were sheathed as part of the building project; the roof was not sheathed to avoid introducing a fall hazard. The shed was designed to include the common types of nailing in residential framing, including flat nailing (used in sheathing), through nailing (studs to top plate), and toe nailing in corners (common roof beams to ridge).

Before beginning the building, the drafted plan for the shed was reviewed with each carpenter; each was given instructions on building specifications that included standard nail spacing. The prototype shed was in the work area and was shown to participants as part of their instruction. Each journeyman was told to build as he would under normal conditions. If he encountered situations when he would normally switch to his hammer, he was told to do so. The same nail guns were used throughout the project, while each participant brought his own tool belt and hand tools (i.e., tape, hammer). He was free to pause or take a break during the building process. Each carpenter adjusted the compressor to power the tools and tested the use of the nail gun prior to beginning the project. Each carpenter was given a proscribed number of pre-counted nails. Any additional nails that the carpenter needed were documented.

Participants did not cut or lay out the materials. In preparation for building each shed, all materials were cut out, marked, and stacked as they were to be used. The mean preparation time for each building, including the cutting and roof layout, was 20 hours, or 1,200 minutes. The participants assembled each wall as part of their building project; the roof layout was done in advance, requiring that the participant only do the nailing. Anticipated building time based on the prototype shed was less than two hours.

The construction of each shed was timed from when each carpenter began until he finished (excluding any breaks). A video recording was also made to capture active building/nailing time. As each wall was completed, a team of instructors from the training school moved the walls. Nails used in each wall, and later the roof, were counted. Nail placement was evaluated for complete or partial misses/poor placement: a nail was considered a complete miss if it did not penetrate the intended receiving structure, such as a nail that missed the stud completely as it went through the plate or plywood; a partial miss involved incomplete penetration, such as when a nail went through the plate or plywood hitting the stud on an angle and coming out. Both create a hazard that is indicative of poor workmanship. Scoring of nail placement was by consensus of two apprenticeship instructors.

ANALYSES

The video data were downloaded in digital format. Each video was reviewed, and extraneous activities captured on the tapes and the associated time were removed, including headers and trailers, periods when instructions were being given or clarified, breaks, times when the walls were being moved out of the work area, or instances in which the work quality was being evaluated. Time for reloading the guns was included in nailing/building time, but times when there were compressor problems were not included. Each carpenter's work was edited as a pair by the same person without knowledge of the trigger configuration being used. After editing, the total time used by the journeymen participants for construction of each building was documented and analyzed along with the questionnaire data and score sheets documenting nail counts and placement.

Descriptive statistics described the participants, the nails used and their placement, and the total time used to construct each building stratified by trigger configuration and order of the building (first or second) for each carpenter. To account for repeated measures on the same individual, mixed linear models were used (Proc Mixed, SAS)[21] to estimate adjusted means of total time required, nails used, and inaccurate nail placement. In each model, the trigger mechanism on the tool being used and the order of the building were entered as independent variables, and the participant identifier was entered as a random effect.

RESULTS

Between November 2005 and April 2006, 10 journeymen carpenters built 20 sheds. All participants were male. They ranged in age from 24 to 48 years (mean = 36.8, median = 36.5) and had been in the union (and trade) for four to 21 years (mean = 13, median = 14). All but one carpenter currently worked in residential carpentry.

Based on the video analyses, the mean time required for the participants' first building project was 5.2 minutes longer than for the second project, and 10.2 minutes longer when the carpenter used the tool with the sequential trigger mechanism (Table 1). There was little difference in the number of nails used, or their placement, by trigger mechanism. The carpenters used a mean of 30 more nails on the first shed they built than on the subsequent one.

There was considerable variability in the time differences by carpenter (Figure). Three of the 10 journeymen had less than three minutes difference

Table 1. Mean times, nails used, and inaccurate nail placements in shed building by order and trigger mechanism

	Means		
	Time in minutes (range)	*Number of nails used (range)*	*Missed placement*
Trigger			
Contact trip	92.8 (78.1–122.3)	1,176 (1,074–1,324)	25 (1–42)
Sequential	103.0 (79.4–141.8)	1,168 (1,022–1,368)	22 (9–42)
Difference in means	−10.2 minutes	8 nails	3 nails
Order			
First	100.5 (81.1–122.3)	1,187 (1,082–1,368)	25 (9–41)
Second	95.3 (78.1–141.8)	1,157 (1,022–1,304)	22 (1–42)
Difference in means	5.2 minutes	30 nails	3 nails

in their two building trials, while others had more than 20 minutes difference. In the multivariate models, there were no significant differences in the mean numbers of nails used or their placement based on trigger configuration or order of the shed building (data not presented), but there were differences in the time required to complete the project (Table 2). The carpenters were able to complete the shed in a mean of 10 fewer minutes when they used the contact trigger tool; order was not significant but is shown in the model. Of note, the covariance parameter estimates were 141.44 for carpenter and 67.10 for the residual, demonstrating that 68% (141.44/[141.44 + 67.10]) of the overall time variance is explained by variability among carpenters. Number of years the individual had been a carpenter was not a significant predictor of the results and was not included in the models.

The time difference by trigger mechanism represents 10% of the overall mean nailing time (97.8 minutes) required by these carpenters to assemble the sheds. Over the whole building project, this number represents 0.77% of the total mean work time required to cut, assemble, and nail the sheds: 10 minutes/1,297.8 (97.8 minutes nailing + 1,200 cut/layout minutes). Based on the supervisor's clock time for the whole project from start to finish, shed construction took a mean of 147 minutes with the contact trip and 148 minutes with the sequential trigger.

DISCUSSION

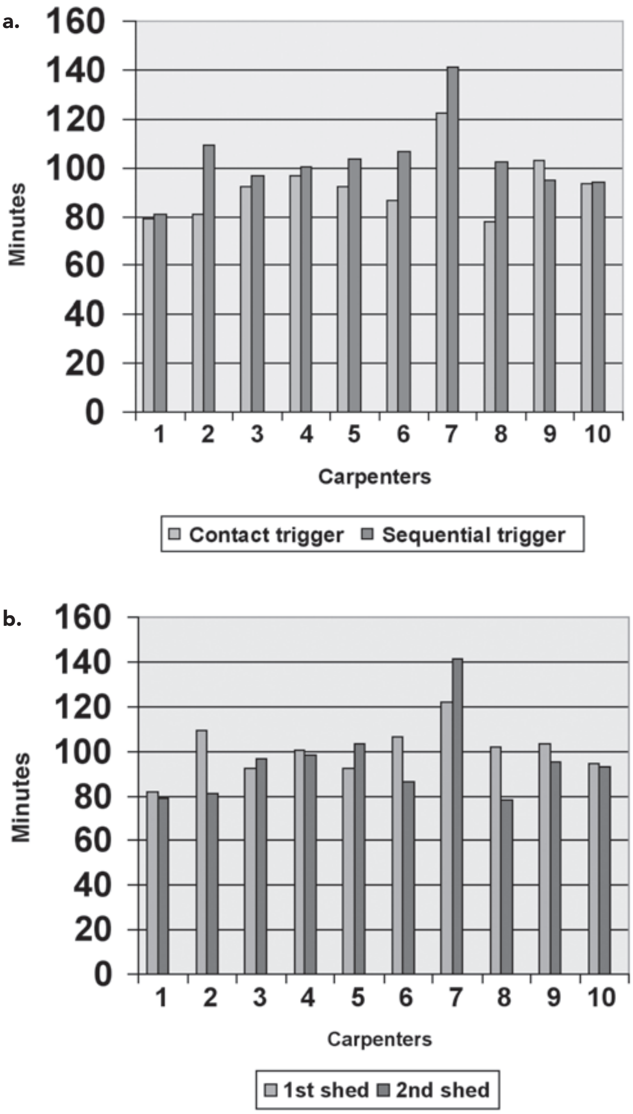
These data, collected under controlled conditions, estimate the potential magnitude of time savings in a framing task through the use of a nail gun with a contact trip trigger vs. a sequential trigger. In this case, the difference accounted for 10% more nailing time with a sequential trigger. Notably, this time difference represented less than 1% of the time required to build these sheds, including cutout, assembly, and nailing. Even among these experienced carpenters, the majority of the time variance (68%) was related to who was using the tool rather than the trigger on the nail gun. We did not find evidence of substantial differences in numbers of nails used or the quality of their placement under the controlled conditions we have described.

There are both limitations and strengths to this work. First, we recruited only journeymen carpenters who had used tools with both trigger configurations. This was done intentionally because of the high risk of injury that has been documented among inexperienced users.[5,20] Consequently, even though we did not see differences among these journeymen based on their varied experiences, we cannot say that our findings apply equally to carpenters at all levels of experience. It is interesting that the major source of the time variability, even among these experienced carpenters, was the user of the tool.

Despite the relatively small number of observations in this experiment, we had adequate statistical power to detect significant differences in adjusted mean nailing time based on the trigger mechanism. The importance from a public health perspective lies not in statistical significance, but rather in the interpretation of whether the differences are meaningful.

The conditions under which these carpenters worked do not replicate real work in residential carpentry. The study's participants were not pushed

Figure. Nailing time required for shed by nail gun trigger configuration and carpenter (a), and sequence and carpenter (b)



to perform rapidly, but they were advised to work as they would normally. Even so, the difference could have influenced results on time and accuracy. All of the building was done in the late afternoon after the carpenters had been working. The conditions (tools, indoor setting, temperature, lighting, and supervising crew) were reasonably comparable on each occasion, and the relative measures we describe are robust to these differences. However, the absolute measures of time could have been influenced by fatigue.

Judgment was required in the process of editing the videotapes. The tapes for each carpenter were intentionally edited in pairs in an attempt to decrease any within-worker coding variability due to the editor's decisions regarding active building/nailing time. The video editor was not advised as to which trigger configuration was being used in the tapes he reviewed. However, the editor became aware of the trigger configuration being used through observation, reporting audible rapid double firing on occasion. We do not believe this influenced the editing time, as there were no particular differences in editing segments early vs. later in the editing process.

Nail gun injuries occur under a variety of circumstances, including accidental discharges, nails that ricochet and become airborne, gun double fires, and penetration of the receiving structure.[4,5,22,23] Factors contributing to injuries vary by the triggering mechanism, and data suggest that more than 50% of injuries from tools with contact trip triggers would be prevented with a sequential triggering mechanism.[4,5,20]

In May 2003, the International Staple, Nail and Tool Association sponsored a voluntary American National Standards Institute standard change calling for the shipping of framing nailers with sequential triggers.[24] Many tools with the contact trip trigger remain in use and, while framing nailers are now commonly shipped with sequential triggers, a contact trip trigger is often shipped in the same box because of concerns about speed in this fast-paced industry.

CONCLUSIONS

Because the majority of variability in time was related to the user and not the trigger mechanism, productivity concerns should focus more on improving the skill of the carpenter rather than on the trigger mechanism

Table 2. Adjusted mean differences, mixed linear model, accounting for multiple measurements per carpenter[a]

	Estimate (SE)	P-*value*
Intercept	100.40 (4.9)	<0.0001
Trigger mechanism		
Contact	−10.2 (3.7)	0.02
Sequential	0	
Order		
First	5.2 (3.7)	0.19
Second	0	

[a]Carpenter entered as a random effect. Covariance parameters are 141.44 for carpenter and 67.10 for residual.

SE = standard error

of the nail gun being used. As safety decisions and further policy changes are considered, it is important to take into consideration the high rate of injuries from nail guns in residential carpentry and the evidence that the majority of injuries from inadvertent or unintentional firings could be prevented through the use of a sequential trigger.[4,5,20] Equally important are the potential ramifications of these common injuries, personally and from the standpoint of medical costs.[6,7] Failure to take the public health approach that would put the safer trigger in the hands of workers implies an apparent acceptance of injury risk that may well have been prevented and does not make sense.

This work was funded through a Cooperative Agreement with the Center to Protect Workers' Rights, Building Trades, American Federation of Labor–Congress of Industrial Unions. All building was done at the Carpenters' Joint Apprenticeship Program (CJAP) in St. Louis, Missouri. The authors are grateful for the use of their space for several months to conduct the work.

The authors also acknowledge the time and efforts of Virgil Walls for preparations, including cutting materials and preliminary layout. The authors thank Steve Bonagurio, Mike Short, Todd Erdman, Jim Schutte, and Tony Cafazza—all of whom are instructors at CJAP—as well as Dan Jones, an instructor at the Southern Illinois Carpenters Training Center in Belleville, Illinois, for their assistance on the days of the building. Finally, the authors thank the 10 journeymen carpenters who participated in this evaluation.

REFERENCES

1. Baggs J, Cohen M, Kalat J, Silverstein B. Pneumatic nailer ("nail gun") injuries in Washington State, 1990–1998. Safety and Health Assessment and Research for Prevention Program. Department of Labor and Industries, Technical report number 59-1-1999.
2. Baggs J, Cohen M, Kalat J, Silverstein B. Pneumatic nailer injuries: a report on Washington State 1990–1998. Professional Safety Magazine 2001;32:33-8.
3. Lipscomb HJ, Dement JM, Li L, Nolan J, Patterson D. Work-related injuries in residential and drywall carpentry. Appl Occup Environ Hyg 2003;18:479-88.
4. Dement JM, Lipscomb HJ, Li L, Epling CA, Desai T. Surveillance of nail gun injuries among construction workers. Appl Occup Environ Hyg 2003;14:665-76.
5. Lipscomb HJ, Dement JM, Nolan J, Patterson D, Li L. Nail gun injuries in residential carpentry: lessons from active injury surveillance. Inj Prev 2003;9:20-4.
6. Lipscomb HJ, Jackson L. Nailgun injuries treated in U.S. emergency departments, 1998–2005. MMWR Morb Mortal Wkly Rep 2007; 56(14):329-32.
7. Lipscomb HJ, Dement JM, Behlman R. Direct costs and patterns of injuries among residential carpenters, 1995–2000. J Occup Environ Med 2003;45:875-80.
8. Kizer KW, Boone HA, Heneveld E, Orozco JR. Nail gun injury to the heart. J Trauma 1995;38:382-3.
9. Jithoo R, Govender ST, Nathoo N. Penetrating nail gun injury of the head and chest with incidental pericallosal artery anerysm. S Afr Med J 2001;91:316-7.
10. Takagi H, Mori Y, Murase K, Hirose H. Nail gun penetrating cardiac injury. Eur J Cardiothorac Surg 2003;23:841.
11. Webb DP, Ramsey JJ, Dignan RJ, Drinkwater DC. Penetrating injury to the heart requiring cardiopulmonary bypass: a case study. J Extra Corpor Technol 2001;33:249-51.
12. Wang MJ, Chen IS, Tsai SK. Nail gun penetrating injury of the left ventricle and descending aorta. Circulation 1999;100:e18-9.
13. Associated Press. Worker shot in head with nail gun. 1998 Jul 17.
14. Associated Press. Man surveys six nails driven into head. 2004 May 6.
15. Associated Press. Nail embedded in man's skull for 6 days. 2005 Jan 17.
16. Brodwater T. Construction worker dies after nail-gun accident. SpokesmanReview.com 2007 Apr 19 [cited 2007 Apr 20]. Available from: URL: http://www.spokesmanreview.com/breaking/story.asp?ID=9950
17. Nadesan K. A fatal nail gun injury—an unusual ricochet? Med Sci Law 2000;40:83-7.
18. Department of Labor, Occupational Safety and Health Administration (US). Inspection Report 1032500, #309967933. Fatality/catastrophe report 2007 Apr 18.
19. American National Standards Institute, International Staple, Nail and Tool Association. ANSI/ISANTA SNT-101-1983. Safety requirements for heavy-duty, portable, compressed-air-actuated, fastener driving tools. 1983.
20. Lipscomb HJ, Dement JM, Nolan J, Patterson D. Nail gun injuries in apprentice carpenters: risk factors and control measures. Am J Ind Med 2006;49:505-13.
21. SAS Institute, Inc. SAS: Version 8.2. Cary (NC): SAS Institute, Inc.; 1999–2001.
22. Beaver AC, Cheatham ML. Life-threatening nail gun injuries. Am Surg 1999;65:1113-6.
23. Edlich RF, Silloway KA, Rodeheaver GT, Morgan RF, Birk K, Thacker JG. Industrial nail gun injuries. Compr Ther 1986;12:42-6.
24. American National Standards Institute, the International Staple, Nail and Tool Association. ANSI/ISANTA SNT-101-2002. Revision of ANSI SNT-101-1993. Safety requirements for portable, compressed-air-actuated, fastener driving tools. 2003.